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ABSTRACT

Intelligence can be best understood through the study of nonentrenched, i.e., novel, kinds of tasks. Such tasks require subjects to use concepts or form strategies that differ in kind from those to which they are accustomed. The only partial success of the cognitive-correlates and cognitive-components approaches to intelligence that are in contemporary favor might be due in part to the use of tasks that are more entrenched (familiar in kind) than would be optimal for the study of intelligence. Two nonentrenched tasks are described, one requiring projection into the future of states of objects, the other requiring complex analogical reasoning where multiple terms of analogies can be replaced by alternative answer options. Research into the first task focused upon performance components of task solution (i.e., components used in the execution of strategy); research into the second task focused upon metacomponents of task solution (i.e., components used in the planning of strategy). Correlations of task and component latencies were generally higher than those obtained in most contemporary information-processing research on the nature of intelligence. Some speculations are made about the implications of these results for educational theory and practice. (Author/RL)

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Intelligence and Nonentrenchment

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Abstract

This article suggests that intelligence can be best understood through the study of nonentrenched, i.e., novel, kinds of tasks. Such tasks require subjects to use concepts or form strategies that differ in kind from those to which they are accustomed. It is suggested that the only partial success of the cognitive-correlates and cognitive-components approaches to intelligence that are in contemporary favor might be due in part to the use of tasks that are more entrenched (familiar in kind) than would be optimal for the study of intelligence. Two nonentrenched tasks are described, one requiring projection into the future of states of objects, the other requiring complex analogical reasoning where multiple terms of analogies can be replaced by alternative answer options. Research into the first task focused upon performance components of task solution (i.e., components used in the execution of strategy); research into the second task focused upon metacomponents of task solution (i.e., components used in the planning of strategy). Correlations of task and component latencies were generally higher than those obtained in most contemporary information-processing research on the nature of intelligence. Some speculations are made about the implications of these results for educational theory and practice.

Intelligence and Nonentrenchment

After several decades of research dominated by a single methodology, that of factor analysis, we have witnessed during the past decade the emergence of several new methodologies for investigating human intelligence. These new methodologies have generated considerable excitement in the field of intelligence, because they have held out the promise of finally answering in a persuasive way Cronbach's (1957) plea for a unification of the two disciplines of scientific psychology, those of experimental and differential psychological investigation.

Two approaches seem to have generated a particularly large amount of theoretical development and empirical research. Pellegrino and Glaser (1979) have referred to these approaches as the "cognitive correlates approach" and the "cognitive components approach." In the cognitive-correlates approach, which has been used by Chiang and Atkinson (1976), Hunt (Hunt, 1978; Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975), Jensen (Jensen, 1979; Jensen & Munro, 1979), and Keating (Keating & Bobbitt, 1978), among others, parameters from simple information-processing tasks of the kind studied in the cognitive psychologist's laboratory (e.g., the letter-matching task of Posner & Mitchell, 1967, and the memory-scanning task of S. Sternberg, 1969) are correlated with scores from psychometric tests of mental abilities. The rationale behind the computation of these correlations is that individual differences in the efficacy with which basic components of information processing are executed underlie individual differences in observed psychometric test performance. In the cognitive components approach, which has been used by Carroll (1976), Egan (1979), Pellegrino and Glaser (in press), and Sternberg (1977, 1979, in press), among others, parameters from complex information-

processing tasks adopted directly from psychometric mental-ability tests (e.g., the shape-rotation task found on spatial ability tests and the analogies task found on reasoning ability tests) are correlated with scores from the psychometric tests. The rationale behind the computation of these correlations is that individual differences in the efficacy with which these components of information processing are executed underlie individual differences in observed psychometric test performance.

The cognitive-correlates approach and the cognitive-components approach are neither mutually exclusive nor exhaustive. That they are not mutually exclusive can be demonstrated in two ways. First, intelligence tests sometimes include very simple perceptual subtests that are quite similar in character to the tasks found in cognitive psychologists' laboratories. Perceptual speed is one of the primary mental abilities in Thurstone's (1938) theory of intelligence, and tests used to measure this ability are essentially the same as the Posner and Mitchell (1967) letter-matching task. Second, a given task can be presented at different "levels of processing" (Sternberg & Powell, Note 1), such that the boundaries between simple and complex tasks become very fuzzy indeed. A "matching" component, for example, might be seen as "lower-order" when used to match physical identities of words, and as "higher-order" when used to match semantic identities of words. But it can also be seen as "intermediate-order" when used to match sounds or numbers of syllables. The correlation between a matching component and a mental ability test score depends at least in part upon the level of processing at which the component is executed (Sternberg & Powell, Note 1; see also Goldberg, Schwartz, & Stewart, 1977; Jackson & McClelland, 1979).

That the two approaches are not exhaustive can be demonstrated simply by citing a limited sample of some of the other kinds of research on intelligence that

are now being conducted. Horn (in press) and Snow (1978), for example, have employed approaches to the investigation of intelligence that make heavy use of information-processing constructs and methodology, but that are also more reliant upon factor-analytic constructs and methodology than are the approaches described earlier. Belmont and Butterfield (1971) and Campione and Brown (1979) have studied executive strategies in memory and intelligence in a way that makes heavy use of information-processing constructs and methodology, but that does not attempt to relate these constructs to psychometric ones. Whitely (in press) has shown how psychometric latent-trait methodology can be combined with information-processing methodology to provide new insights into how components of reasoning enter into general intelligence. To summarize, the cognitive-components approach and the cognitive-correlates approach are neither mutually exclusive nor exhaustive; but they characterize much of the research that has been done on intelligence during the past decade. Moreover, the problems that they have encountered (to be described below) are problems for other current approaches as well.

The cognitive-correlates approach and the cognitive-components approach have somewhat different goals in their correlational analyses. The investigator following the cognitive-correlates approach has no guarantee that there is any relationship at all between components of his or her very simple tasks and performance on complex tests. Hence, this investigator's primary goal is to show a substantial relationship between at least some of the components of simple tasks and scores on complex tests. The investigator following the cognitive-components approach should be guaranteed, if his or her information-processing analysis is correct, that at least some components of his or her complex tasks are related to performance on complex tests. After all, the tasks and the tests are essentially the same! Hence, this investigator's pri-

mary goal is to show a sensible and interesting pattern of relationships between components of complex tasks and performance on complex tests. The question here, then, is which components correlate, rather than whether any components correlate.

As initial attempts to integrate differential and cognitive psychological methodologies, both the cognitive-correlates approach and the cognitive-components approach should be judged as quite successful. They have established new theoretical bases for research on intelligence that complement the already existing theoretical bases (see Sternberg, in press ; Note 2); they have shown that a combination of differential and experimental methodologies can provide a more nearly complete theoretical account of intelligent functioning than can either approach taken singly (see Carroll, 1976; Hunt, 1978; Sternberg, 1977, in press); and they have provided empirical data that provide at least a beginning toward understanding the information-processing bases of intelligent performance (see Hunt et al., 1973, 1975; Pellegrino & Glaser, in press; Sternberg, 1977; Sternberg, Guyote, & Turner, 1980). I suspect that within just a few years, however, these initial attempts at combining differential and experimental approaches to intelligence will be viewed retrospectively as having told us as much about how we should not do such research as about how we should do it.

The cognitive-correlates approach was always suspect, in my opinion, because its adherents chose to understand individual differences in intelligence in terms of performance on (a) very simple cognitive tasks that (b) just happened to be the ones cognitive psychologists (many of whom had no particular interest in intelligence) were studying at the time in their laboratories. I did not expect impressive correlations of latency parameters from very simple tasks with global or factor scores from very complex tests,

and the correlations have not, in fact, been impressive. They have generally been at the same meager level--roughly from .20 to .40--as have been the so-called "personality coefficients" (Mischel, 1968) that have plagued the literature on relationships between personality tests that supposedly measure the same or similar things. In the past, the psychometric literature on intelligence has been distinguished from that on personality largely because of the higher correlations—roughly from .40 to .80--that have been demonstrated between intellectual tests that supposedly measure the same or similar things. In one respect, therefore, the cognitive-correlates literature might be viewed as retrogressive, placing intelligence research on a footing similar to that of psychometric personality research. This retrogressive effect is probably more than counterbalanced by the progressive effect of putting intelligence research into a cognitive-theoretical framework. But it would be desirable to reestablish correlations between measures at the same level as those in the psychometric literature on intelligence, while at the same time maintaining the strong theoretical basis introduced by the cognitive-correlates or any other approach.

I had higher hopes for the cognitive-components approach, if only because the tasks that were analyzed had the face validity that the tasks used by adherents to the cognitive-correlates approach lacked. Some adherents of this latter approach argued with me (orally, although I believe never in print) that using the same tasks as were found on intelligence tests trivialized the whole enterprise, since one was in effect guaranteeing a respectable level of correlation. After all, the tasks were essentially the same. But this argument would be persuasive only if one's primary goal in using the cognitive-components approach were to demonstrate any correlation at all between task parameters and test performance. The primary goal of this research, however,

is to demonstrate a meaningful pattern of correlations between task parameters and test scores. The data of primary interest are in the patterns of correlations; the magnitudes of the correlations are only of secondary interest, and what is of interest is which correlations are high, not whether any correlations are high. Thus, one seeks to demonstrate which information-processing components required by intelligence tests are the ones that require "intelligence"--and for this purpose, the cognitive-components approach is not trivial at all. The problem with this approach as it has been constituted has turned out to be that sometimes the pattern of correlations is meaningful, and sometimes it is not. My reading of the literature collected so far is that the patterns of correlations have been quite sensible for studies of deductive reasoning (see Sternberg, in press ; Sternberg & Weil, 1980; Sternberg, Guyote, & Turner, 1980), but not as sensible for studies of inductive reasoning (see Mulholland, Pellegrino, & Glaser, in press; Sternberg, 1977) and of spatial ability (see Egan, Note 3). These latter abilities seem to come closest to what Horn (in press) refers to as "fluid ability," and they include items of the kinds most commonly found on tests of general intelligence (or "g"), such as analogies, series completions, classifications, and form rotations. The patterns of correlations for these kinds of items are by no means completely meaningless. In fact, all but one of a large number of correlational findings seem to make very good sense (Sternberg, 1977, 1979; Sternberg & Rifkin, 1979). But the one perplexing finding is troubling indeed: It is a high and replicable correlation between the regression intercept (constant) and intelligence test scores. The regression intercept is usually alleged to measure response component time plus whatever else is constant across all item types within a given data set. Part

of the correlation may in fact derive from the response component: There is now good evidence to suggest that choice reaction time correlates significantly with measured intelligence (Jensen, 1979; Lunneborg, 1977). But the obtained correlations between the regression intercept and ability test scores have been persistent and high enough to lead some people, including myself, to believe that there may be one or more critical components of intelligent performance that are not now being extracted by componential procedures of task decomposition (see Sternberg, 1978). Thus, whatever it is that we are interested in most may be confounded with response, which is probably what it is that we are interested in least.

During the past couple of years, my collaborators and I at Yale have been pursuing the notion that the stumbling block we have encountered derives not from the inadequacies of the cognitive-components (or componential) approach, but from the inadequacies of the psychological conceptions that have served as the theoretical bases for applications of the methodology. On our view, the peculiar correlation of the response component with measured intelligence has demonstrated the strength rather than the weakness of the cognitive-components approach: The data yielded by the approach have highlighted rather than concealed the inadequacies of our psychological theories. Where the theories have been adequate, the data have made sense; where the theories have been inadequate, the data have not made sense. Our task, then, has been to figure out what is wrong with our theories, and to attempt to right whatever it is (see Sternberg, 1980).

Our basic research strategy has been to study people's performance on what we refer to as "nonentrenched tasks." By nonentrenched tasks, we mean tasks that require conceptualizations--in particular, strategy planning and strategy execution--of a kind different from those required in the typical,

or "entrenched tasks" used in standard laboratory and psychometric paradigms. Our view, which is a time-honored one for which we claim no originality, is that intelligence is in large part the ability to acquire and reason with new conceptual systems. It is not merely the ability to learn and reason with new concepts, but the ability to learn and reason with new kinds of concepts. What makes a person intelligent is not so much the person's ability to learn or think within conceptual systems the person has already become familiar with, as his or her ability to learn and think within new conceptual systems, which can then be brought to bear upon already existing knowledge structures. Thus, an intelligent person must first learn a new conceptual system, and then see how it applies (analogically) to old problems.

This view seems consistent with many of our everyday notions about intelligence, if not with our research about it. A student is likely to be considered more intelligent if he or she can master a new kind of course (say, calculus or foreign language) than if he or she can master another course that differs in substance but not in kind from courses the student has taken previously. We tend to be less impressed with students (or scientists, for that matter) who merely demonstrate time and again the competence they have already demonstrated many times before than we are with students (or scientists) who are continually demonstrating new kinds of competences. Indeed, the most successful students and scientists are often those who bring new conceptual systems to bear on old problems. Carrying this line of argument one step further, I would argue that the ability to perform mundane tasks, such as following a recipe in a cookbook, may demonstrate intelligence, but seldom in an interesting way, unless a novel approach is brought to bear on that task. But the tasks we have used to study intelligence have often been ones that discourage the formation of novel approaches, and our concern

with "right" and "wrong" answers often discourages novel thinking even if it is a possibility. Psychometricians have long been accused, probably rightfully, of being concerned in their data analyses only with the products of performance and not with the processes of performance. If new approaches to solving problems were brought to bear, they would probably never know it. Information-processing psychologists would seem to be innocent on this score, given their obvious concerns with strategy in information processing. But they, too, are culpable in at least some degree. First, the large majority of them conduct data analyses only on correct performance, throwing out the error data that might contain at least some information of interest. And the differences in strategy that they have studied have often been studied in the context of tasks that just don't encourage new ways of thinking (but see, in contrast, the work of Newell & Simon, 1972, and others interested in complex problem solving). The study of thinking in nonentrenched or unconventional kinds of tasks seems to hold some promise for the study of intelligence, and perhaps, eventually, of creativity.

I describe in this article two studies we have undertaken that use nonentrenched tasks that subjects in the study were extremely unlikely ever to have performed before. The studies involve very different kinds of tasks, but of greater importance is the fact that their theoretical motivations were quite different. The first set of experiments pursues the notion that performance components, i.e., information-processing components used in strategy execution, can be critical indicants of intelligence when the components are essential ones isolated from nonentrenched tasks. The second set of experiments pursues the notion that metacomponents, i.e., information-processing components used in strategy formation, can be critical indicants of intelligence when the components are essential ones isolated from nonentrenched tasks.

Indeed, it may be that metacomponents can be isolated only from nonentrenched tasks. The standard information-processing tasks that have been studied in the past seem virtually always to fail to manipulate in a systematic way difficulty of strategy planning. Items are of differential difficulty because a given strategy is easier to harder to execute, not because it is easier or harder to form a strategy. Thus, metacomponential strategy formation time is confounded with the regression intercept (constant), and may be in part what is responsible for the high correlation of the regression intercept with measured intelligence (see Sternberg, 1979).[1]

Isolation of Performance Components from a Nonentrenched Task

The first nonentrenched task to be described is a "projection task" that was originally studied for reasons quite different from those that are of interest in the present article.[2] The basic task is to make a projection that characterizes the state of an object at some future time on the basis of incomplete information about the state of the object both at that time and at some earlier time. Formulation of the task was motivated by Nelson Goodman's (1955) "new riddle of induction," which poses the problem of why people make certain projections about the future and not others when the evidence in favor of the alternative projections is equally favorable. The projection task was studied with three different "surface" structures having very similar "deep" structures. Consider the first instantiation of the task, which requires projection of the color an object will appear to be at a future time.

In the first instantiation of the task, subjects were presented with a description of the color of an object in the present day and in the year 2000. The description could be either physical--a green dot or a blue dot--or verbal--one of four color words, namely, green, blue, grue, and bleen. An object was

defined as green if it appeared physically green both in the present and in the year 2000. An object was defined as blue if it appeared physically blue both in the present and in the year 2000. An object was defined as grue if it appeared physically green in the present but physically blue in the year 2000 (i.e., it appeared physically green until the year 2000, and physically blue thereafter). An object was defined as bleen if it appeared physically blue in the present but physically green in the year 2000 (i.e., it appeared physically blue until the year 2000, and physically green thereafter).

Since each of the two descriptions (one in the present and one in the year 2000) could take one of either two physical forms or four verbal forms, there were 6 x 6, or 36 different item types. The subject's task was to describe the object in the year 2000. If the given description for the year 2000 was a physical one, the subject had to indicate the correct verbal description of the object; if the given description for the year 2000 was a verbal one, the subject had to indicate the correct physical description of the object. There were always three answers choices from which the subject had to choose the correct one.

Subjects were alerted to a complexity in the projection task that applies to the real world as well. When one observes the physical appearance of an object in the present day, one can be certain of its current physical appearance, but not of what its physical appearance will be in the year 2000. Hence, all descriptions presented for the present day could be guaranteed to be accurate with respect to physical appearance in the present, but they could not be guaranteed to be accurate with respect to their implications, if any, regarding physical appearance in the future. For physical descriptions of objects as they appear in the present, this complexity presents no problem, since the physical description of an object (a green dot or a blue dot) carries

no implication regarding the future physical appearance of the object. For verbal descriptions of objects as they appear in the present, however, this complexity does present a problem. The verbal descriptions "blue" and "green" imply constancy in physical appearance, whereas the verbal descriptions "grue" and "bleen" imply change. Unfortunately, all one can infer with certainty from these verbal descriptions is the current physical appearance of the object. The implication for the future physical appearance of the object can only be a guess, which may be right or may be wrong. This complexity ceases to exist for the observation in the year 2000, because at this point all of the evidence is in. The observer in the year 2000 knows for certain what the physical appearance of the object is in 2000, and also knows for certain what the physical appearance of the object was in what was once the present. Hence, the second description, that of the object in the year 2000, is guaranteed to be correct both with respect to the object's appearance in 2000 and the object's appearance in what was once the present. (The one exception to this guarantee is in "inconsistent" problems, which are described in the subsequent examples.) In the year 2000, the description no longer represents a projection; it represents a fact. To summarize, physical descriptions, which carried no implication for what an object would look like at another time, were always accurate in all respects. Verbal descriptions, which did carry an implication for what an object would look like at another time, were always accurate with respect to the physical description they implied for the time at which the description was given (except for the inconsistent items to be described), but in the present, they might not be accurate with respect to the physical description they implied for the year 2000.

Some examples of actual items will illustrate the types of problems and the range of difficulty exhibited by the projection items. In these examples, the letters "G" and "B" will be used to represent the colored dots (green or blue) that were used to represent physical appearances in the actual stimulus

items. Recall that items could consist of either two verbal descriptions, a physical description followed by a verbal description, a verbal description followed by a physical description, or two physical descriptions:

Example 1. BLUE BLUE G B I

In this example, an object is described verbally as "blue" in the present and as "blue" in 2000. Clearly, its physical appearance in 2000 is "B." (The letter "I" stands for "inconsistent," and its use is described in the next example.) This was an easy item, with a mean response latency of 1.5 seconds.

Example 2. BLUE GREEN I B G

In this example, an object is described verbally as "blue" in the present but as "green" in 2000. These two items of information are inconsistent with each other, and hence the correct answer is "I." If the physical appearance of the object changes from blue in the present to green in 2000, the appropriate verbal description of the object in the year 2000 is "bleen." If the physical appearance of the object does not change, the appropriate verbal description in the year 2000 is "blue." But an object cannot correctly be described as "green" in the year 2000 if its physical appearance was formerly blue. This item was of moderate difficulty, with a mean response latency of 2.5 seconds.

Example 3. BLUE BLEEN I G B

In this example, an object is described verbally as "blue" in the present but as "bleen" in 2000. The physical appearance of the object in the present is thus blue, and it is predicted that this physical appearance will not change. The description of the object in the year 2000 indicates, however, that the prediction was incorrect: The physical appearance of the object changed to green. Hence, the object is described as "bleen" in the year 2000. As stated earlier, there is no guarantee that implications regarding future appearances of an object will be correct. In this case, the implication was incorrect.

The correct answer is "G." This item was a fairly difficult one, with a mean solution latency of 3.3 seconds.

Example 4. B GREEN B G I

In this example, an object is described as physically blue in the present, but as verbally "green" in the year 2000. An item cannot be correctly described as "green" in the year 2000, however, if its physical appearance was blue at an earlier time. Hence, the correct answer is "I." This item was moderately difficult, with a mean solution latency of 2.9 seconds.

Example 5. G GRUE G B I

In this example, an object is described as physically green in the present, but as verbally "grue" in the year 2000. The object thus must have appeared physically green in the present and physically blue in 2000. The correct answer is "B." This item was also moderately difficult, with a mean solution latency of 3.1 seconds.

Example 6. GREEN B GRUE BLEEN GREEN

In this example, an object is described verbally as "green" in the present, and is described physically as "B" in 2000. One can infer that its physical appearance changed from green to blue. The prediction in the present that physical appearance would not change was incorrect. The correct answer is "grue." This was a difficult item, with a mean solution latency of 3.6 seconds.

Example 7. BLEEN B GREEN BLEEN BLUE

In this example, an object is described verbally as "bleen" in the present, and is described physically as "B" in 2000. One can infer that its physical appearance remained in 2000 what it was in the present, blue. The prediction that the object would change in physical appearance was incorrect. The correct answer is "blue." This was a very difficult item, with a mean solution latency of 4.3 seconds.

Example 8. B G BLEEN GREEN GRUE

In this example, an object is described physically as "B" in the present and as "G" in 2000. The correct verbal description of the object in 2000 is "bleen." This is a difficult item, with a mean solution latency of 3.5 seconds.

Consider now briefly the second instantiation of the projection task, which was seen by subjects different from those participating in the first experiment (instantiation). In this experiment, based upon appearances of objects on the planet Kyron, an object is described as "plin" if it appears solid north of the equator and solid south of the equator, as "kwef" it it appears liquid north of the equator and liquid south of the equator, as "balt" if it appears solid north of the equator but liquid south of the equator, and as "pros" if it appears liquid north of the equator but solid south of the equator In each case, subjects were told that knowledge about the object was obtained first regarding its state north of the equator and then regarding its state south of the equator. Knowledge was acquired by transporting the object from north to south of the equator. Hence, "north of the equator" corresponds to "the present" in the first experiment, and "south of the equator" corresponds to "the year 2000" in the first experiment. Physical representations of objects were either a filled dot (for solid physical appearance) or a hollow dot (for liquid physical appearance).

In the third instantiation of the projection task, which was seen by still different subjects, the same four new words were again used, but their meanings were different. Four types of persons were alleged to live on the planet Kyron. A person was described as "plin" if the person was born a child and remained a child throughout his or her life span. A person was described as "kwef" if the person was born an adult and remained an adult throughout his or her life span. A person was described as "balt" if the person was born

a child but became an adult during the course of his or her life span. And a person was described as "pros" if the person was born an adult but became a child during the course of his or her life span. A stick picture of a little person was used for the physical representation of a child; a stick picture of a big person was used for the physical representation of an adult.

Each of the approximately 25 subjects in each of the three experiments received detailed task instructions, followed by practice items, followed by the actual task items, followed by psychometric ability-test items. The ability-test items were three kinds of series extrapolation problems: abstract (geometric) series, letter series, and number series. In each case, the subject had to choose which of four possible answer options best completed a given series. The items were taken from standardized intelligence tests. Subjects in the three experiments were Yale undergraduates participating for pay, course credit, or both. Each subject in each experiment saw each of the 36 item types three times, once with the correct answer in each of the three possible ordinal positions.

The three instantiations of the projection task were of unequal difficulty. Mean solution latencies were 3.02 seconds for the first experiment, 5.44 seconds for the second experiment, and 4.15 seconds for the third experiment. Mean error rates were .04, .13, and .05 for the three respective experiments. These data suggested that the third instantiation of the task (life-course differences) was slightly more difficult than the first instantiation of the task (color differences), and that the second instantiation of the task (consistency differences) was quite a bit more difficult than either of the other two instantiations of the task.

Correlations were computed between scores on the projection task and composite z-score on the three ability tests. The correlations of response latencie

with the ability test scores were -.69 ($p < .001$), -.77 ($p < .001$), and -.48 ($p < .05$) in the three respective experiments. Correlations between error rates and ability test scores were in the predicted direction, but were nonsignificant. The correlations of the latencies with ability test scores are higher not only than those usually obtained in cognitive-correlates research that uses very simple tasks, but are also higher than those usually obtained in standard cognitive-components research that uses complex tasks similar or identical to those found on mental-ability tests. The high magnitudes of the present correlations, obtained with three different instantiations of the projection task and with three different groups of subjects, are of particular interest because the projection task is not one found on mental-ability tests. Hence, the high correlations are not due simply to the task being correlated with itself, with only the mode of presentation (tachistoscope versus pencil-and-paper) and the dependent variable (solution latency versus number correct) varying. Instead, the task seems to tap some interesting aspect of intelligent behavior that is not tapped in this way on standard ability tests.[3]

A complete componential analysis of the projection task requires the isolation of the locus or loci of the high overall correlations that have been obtained. At minimum, one would wish to show a sensible pattern of correlations between task parameters and ability test scores. In order to perform this kind of analysis, it is necessary to formulate, quantify, and test an information-processing model of task performance. These things have been done (Sternberg, Note 4), and the outcomes are described here.

According to the proposed information-processing model of projection-task performance, subjects initiate problem solution by IDENTIFYING THE FIRST PREMISE

(e.g., that an object appears physically green in the present). Next, they ACCESS THE CONCEPTUAL SYSTEM appropriate to this premise (e.g., either the system for physical appearances; for "green-blue" language, i.e., English; or for "grue-bleen" language). If the first premise is a word, subjects DECODE THE WORD INTO A PHYSICAL REPRESENTATION. If the word is a variable-state word (such as "grue" or "bleen"), subjects ENCODE AN EXPECTATION OF A CHANGE IN PHYSICAL REPRESENTATION. Next, regardless of whether or not the first premise was a word, subjects STORE THE PHYSICAL REPRESENTATION of the object represented by the first premise.

Subjects are now ready to process the second premise. First, they go about IDENTIFYING THE SECOND PREMISE (e.g., that an object appears physically blue in the future). If this premise requires a new conceptual system, i.e., a conceptual system different from the one required by the first premise, subjects ACCESS THE NEW CONCEPTUAL SYSTEM; otherwise, subjects stay with the same conceptual system that they have previously accessed. If the second premise takes the form of a word, subjects DECODE THE WORD INTO A PHYSICAL REPRESENTATION. Next, subjects STORE THE PHYSICAL REPRESENTATION of the object represented by the second premise.

Subjects are now prepared to compare information contained in the two premises. If there is a change in physical representation from the first premise to the second (e.g., from physical green to physical blue), and if there is a violation of an expected constancy in physical appearance (e.g., an object is expected to remain green in physical appearance but changes to blue in physical appearance), then subjects ALLOW FOR THE POSSIBILITY OF A CHANGE IN PHYSICAL REPRESENTATION. If there is a change in physical representation, but no violation of an expected constancy, then subjects merely need FIND THE APPROPRIATE VARIABLE-STATE CONCEPT (which they must do in any case after they allow for

the possibility of a change in physical representation). Next, all subjects READ THE ANSWER OPTIONS. If the options are words, then subjects DECODE MEANINGS OF THE WORDS IN THE ANSWER OPTIONS. Next, subjects SELECT AN ANSWER, and finally, they RESPOND.

Each information-processing component represented above by a phrase of capitalized words constituted a hypothesized source of incremental latency in information processing. The model proposed that total solution latency was the sum of the component latencies. Quantification procedures (described in Sternberg, Note 4) permitted estimation of some but not all of the parameters representing durations of individual components. Some components were confounded in the regression constant; others were not so confounded, but when estimated, failed to yield latencies that were long enough to generate statistically significant parameter estimates. Most parameters could be estimated, however, and were in fact estimated in testing of the model.

The model was quite successful in accounting for the group-mean data. Squared correlations (R^2) between predicted and observed solution latencies were .94, .92, and .94 in the three respective experiments, with 12, 13, and 11 residual degrees of freedom respectively. Residuals of observed from predicted values were statistically significant only in the third experiment. Root-mean-square deviations of observed from predicted latencies were .20, .43, and .25 seconds in the three experiments. The model provided a good fit to individual-subject as well as to group-mean data. When the model was fit to the data of each individual subject, and the individual values of R^2 were averaged across subjects, the mean R^2 values were .76, .63, and .67 in the three respective experiments. There is thus good reason to believe that the model provided a good account of what many (if not all) subjects were doing when they solved projection-task problems.

Values of parameters were generally quite sensible, and in the two experiments having items of similar difficulty (1 and 3), parameter values were quite consistent in value. Indeed, the correlation between estimated parameter values in the first and third experiments (for the six parameters that could be estimated in each experiment) was .997, with an unstandardized regression slope of .95 and a regression intercept of .07. Parameter values in the second experiment tended to be higher than in the first and third experiments (as would be expected), but similar in pattern to those of the other two experiments, with one notable exception: The regression intercept was much greater in the second experiment (2.55 seconds) than in the first experiment (.81 second) or the third experiment (.88 second). In general, the longest estimated latencies were for parameters involving comparison of the objects described in the first and second experiments, namely, FIND THE APPROPRIATE VARIABLE-STATE CONCEPT (1.46 seconds, 2.31 seconds, and 1.47 seconds in the three respective experiments), and ALLOW FOR THE POSSIBILITY OF A CHANGE IN PHYSICAL REPRESENTATION (1.49 seconds, 1.22 seconds, and 1.45 seconds in the three respective experiments). The shortest parameter estimate was one for simple word recognition, DECODE MEANINGS OF THE WORDS IN THE ANSWER OPTIONS (.35 second in each of Experiments 1 and 3; nonsignificant in Experiment 2

Of greater importance for our present purpose is the pattern of correlations between the parameter estimates and the ability-test scores. As might be expected, the highest correlations were obtained for parameters measuring latencies of components requiring processing of variable-state words (like "grue" and "bleen") and new conceptual systems. The correlationsbetween FIND THE APPROPRIATE VARIABLE-STATE CONCEPT and the ability-test composite were -.59, -.60, and -.14 in the three respective experiments. The first two correlations were highly significant; the third was not significant. The correlations between ACCESS THE

NEW CONCEPTUAL SYSTEM and the ability-test composite were -.45, -.42, and -.13 in the three respective experiments. Again, the first two correlations were significant; the third was not.

Recall that the overall correlation of solution latency with the ability-test composite was lower in the third experiment than in the first two, and as can be seen above, the parameter correlations with the ability-test composite were also lower (as would be expected). What might account for the difference in magnitudes of the correlations? A reasonable speculation relates to the concept of "nonentrenchment" as it applies within each experiment. In the first two experiments, the variable-state concepts (changing color over time or changing physical consistency over time and place) were nonentrenched with respect to our everyday experience: Objects are not expected to change in color in the year 2000, or to change in physical consistency when transported to the opposite side of the equator. The constant-state concepts (retention of color over time or retention of physical consistency over time and place) were entrenched with respect to our everyday experience: We expect objects to remain the same color in the year 2000, or to retain their physical consistency when transported across the equator. Thus, in the first two experiments, changes in physical state and nonentrenchment, both of which contributed to solution latency (see Sternberg, Note 4), "worked together," as did constancies in physical state and entrenchment, each of which were associated with shorter solution latencies. In the third experiment, one kind of change in physical state (from being an adult to being a child) was nonentrenched with respect to our everyday experience, but the other kind of change in physical state (from being a child to being an adult) was entrenched with respect to our everyday experience. And unlike in the first two experiments, constancy of physical state (remaining an adult or remaining a child over one's life span) were

nonentrenched. Hence, in the third experiment, changes in physical state were nonentrenched only half the time, and constancies in physical state never were. The two sources of added solution latency did not "work together" in this experiment. The items in this experiment might therefore have been less suitable for measuring individual differences in intelligence, which are proposed here to reflect at least in part the ability to reason with (transformations of) nonentrenched concepts.

In the first and third experiments, the regression intercept was only trivially correlated with the ability-test composite. Correlations were -.18 and .10 for the two respective experiments. In the second experiment, however, a highly significant correlation of -.59 was obtained. Why might this experiment, but not the other two, have yielded a high correlation between the regression intercept and ability-test performance? I suspect it might be because of the greater complexity of the instructions for this experiment. It appears that an important part of intelligence is the ability to solve a task on the basis of incomplete or difficult instructions (see Resnick & Glaser, 1976), and this task variant involved particularly difficult instructions. Since the instructions were constant across items, any instructional effects would be likely to end up in the regression constant. I am now running a second version of the second task variant with simplified instructions in an attempt to test this proposal.

To summarize the results of this set of experiments, nonentrenchment appears to be a key concept in the understanding of intelligence. The concept applies both to tasks and to conditions within tasks. The ability to perform nonentrenched tasks successfully, and to process nonentrenched concepts within such tasks, appear to be consequential in individual differences in measured intelligence. Performance components involving processing of nonentrenched

concepts in nonentrenched tasks can be highly correlated with measures of intellectual ability.

Isolation of Metacomponents from a Nonentrenched Task[4]

The second nonentrenched task to be described is a complex analogical reasoning task that, like the projection task, was originally studied for reasons having nothing to do with nonentrenchment. The basic task is to solve verbal analogies correctly but in as little time as possible. The analogies differ from standard analogies, however, in that it is possible for from one to three analogy terms to be missing, and in that the positions of missing terms vary from one problem to another. Either two or three alternative answer options are substituted for each missing analogy term. In this respect, the problems are like ones used by Lunzer (1965) to study the development of analogical reasoning processes. An example of such a problem is MAN : SKIN :: (DOG, TREE) : (BARK, CAT). The correct answers are TREE and BARK. The complete set of formats includes

$A_i : B :: C : D$	$A_i : B :: C : D_i$
$A : B_i :: C : D$	$A : B_i :: C_i : D$
$A : B :: C_i : D$	$A : B_i :: C : D_i$
$A : B :: C : D_i$	$A : B :: C_i : D_i$
$A_i : B :: C_i : D$	$A : B_i :: C_i : D_i$

where terms with the subscript i are missing ones with either two or three answer options substituted.

Performance on problems such as these could be understood in terms of a componential theory of analogical reasoning (Sternberg, 1977), but our particular interest was not in the performance components used to solve the problems, but in the metacomponents used to decide how to solve the problems. In particular, we were interested in isolating latencies for two forms of strategy

planning, which we referred to as "global planning" and "local planning."

Global planning refers to the formation of a macrostrategy that applies to a set of problems, regardless of the particular characteristics of a particular problem that is a member of a given set. The need for global planning can be largely a function of the context in which a set of problems is presented. We manipulated the amount of global planning required by presenting sets of analogies in two conditions, one mixed and the other blocked. In the mixed condition, each analogy within a given set of 10 items was of a different one of the formats described above. Subjects in this condition were presumed to need considerable global planning to deal with the fact that problems within a given problem set were of a constantly shifting nature. Regardless of the particular item type encountered at a particular time, this item context is not conducive to rapid or automatic planning of global strategy. In the blocked condition, all analogies within a given set of 10 items were of the same format, i.e., were the same with respect to the positions of the missing terms. Subjects in this condition were presumed to need less global planning, since all items within a given set were of the same structural format. Once a strategy was planned, it could be followed for all problems with minimal or no revision.

Local planning refers to the formation of a microstrategy that will be sufficient for solving a particular problem within a given set. Whereas global planning is assumed to be highly sensitive to the context of the surrounding problems, local planning is assumed to be context insensitive, applying to each item individually. It consists of the specific planning operations that are needed for a given item (e.g., tailoring the global plan to a specific item). We manipulate the amount of local planning required by presenting analogies in the various formats described above. More "difficult" formats were assumed to require more local

planning; less "difficult" formats were assumed to require less local planning. Difficulty of a format was defined in terms of a strategic complexity index that might also be viewed in part as an index of the nonentrenchment of a given item type. For example, items having more familiar formats, such as A : B :: C_i : D_i, might be viewed as more entrenched with respect to our past experience than items having less familiar formats, such as A : B_i :: C : D_i. The first format is commonly found on mental ability tests, such as the Scholastic Aptitude Test. The second format is not found on such tests.

In order to solve the analogies, subjects also had to execute performance components that actually implemented the strategy or strategies formulated by the metacomponents. We used my componential theory of analogical reasoning (Sternberg, 1977) to calculate the numbers of executions of performance components that would be required to solve items of each given type. Since our primary interest was in isolating metacomponents rather than in isolating performance components, we simply summed these numbers of executions into a single composite index, which represented the total number of executions of performance components required to solve analogies of a given type.

In addition to solving analogies tachistoscopically, subjects also solved items presented in pencil-and-paper format. These items were from the Raven Progressive Matrices and from two letter-series completion tests. The first letter-series test was from the SRA Primary Mental Abilities; the second was homemade.

We have now collected and analyzed data from 20 of the 30 subjects we eventually plan to test. Mean solution latency for the 20 different complex analogy types (10 formats x 2 different numbers of answer options) was 9.00 seconds. Mean error rate was 14%. A simple additive model with four parameters--global strategy planning, local strategy planning, performance component

execution, and a regression constant representing response and other processes constant across item types—accounted for .97 of the variance in the mean latency data. Since the reliability of the latency data was .98, the fit of the model can be considered to be quite good. The model also provided good fits to individual data. Values of R^2 for individual subject data ranged from .71 to .92, with a mean of .85. Only one subject had an individual R^2 of less than .83.

All parameters of the model were statistically significant at the 5% level. Standardized parameter estimates (beta weights) were more interpretable than unstandardized estimates (raw weights), because one of the independent variables, that used to estimate local planning time, was not formulated as a real-time index. The standardized parameter estimates were .43 for the performance components, .04 for global planning, and .19 for local planning. Unstandardized estimates showed the same pattern. Apparently and expectedly, subjects spent most of their time actually solving the problems. A relatively substantial amount of time went into the planning of strategy for each individual problem, however. Much less time went into global planning, as would be expected, since the blocked condition required much less global planning than the mixed condition, whereas the need for local planning was constant across conditions.

Latency scores for individual subjects were correlated with scores from the two kinds of ability tests (matrix problems and letter series completions for the two series tests combined). Since performance on the matrix problems was not correlated with either latency scores or performance on the letter-series tests, the matrix problems were removed from further consideration. Correlations were -.54 for all stimulus items combined, -.54 for items presented in the blocked condition, and -.53 for items presented in the mixed condition. Parameter estimates were computed in two different ways (see Sternberg & Salter, Note 5). Both sets of parameter estimates showed the same correlational patterns with the letter series composite. The mean correlation between the composite of the letter

series tests and the average of the parameter estimates was -.42 for the execution of performance components, .43 for global planning, -.33 for local planning, and -.40 for the regression constant. All correlations were statistically significant at the 5% level, except that for local planning (the nonentrenchment parameter), which was only marginally significant at the 10% level. The multiple correlation between the letter series composite score and an optimal combination of the four parameters was .64.

These correlations suggest several things. First, a composite of straightforward performance components of the kind that have been studied in previous investigations of analogical reasoning (e.g., Mulholland, Pellegrino, & Glaser, in press; Sternberg, 1977; Sternberg & Rifkin, 1979) and other kinds of reasoning (e.g., Sternberg, Guyote, & Turner, 1980) is moderately related to scores on a paper-and-pencil reasoning test composite. As would be expected, shorter latencies were associated with higher numbers correct on the paper-and-pencil test. Second, global planning, a metacomponent, is also moderately related to scores on the reasoning test composite. Of particular interest is the fact that this correlation is positive, indicating that longer global planning latencies were associated with higher reasoning scores. This result is strongly reminiscent of previous findings (see Sternberg, 1977; Sternberg & Rifkin, 1979) indicating that better reasoners tend to spend more time encoding the terms of a problem than do poorer reasoners, but tend to spend less time operating upon these encodings than do poorer reasoners. Similarly, it now appears that the better reasoners tend to spend more time in global planning of a strategy for problem solution, but less time in local planning and in actual execution of the global strategy. Third, local planning is at least weakly related to scores on the reasoning test composite. The measure of local planning difficulty was not a real-time based one, and

we have hopes that a more sophisticated measure of local planning difficulty might improve the correlation of local planning latency and measured inductive reasoning ability. Finally, the regression constant was still significantly related to scores on the reasoning composite. Hence, the experiment did not succeed in extracting all interesting sources of individual-differences variance from the regression constant. We realize in retrospect that one difficulty in extracting interesting sources of variance from the constant is that the experimental paradigm needed to do this tends to be one that is, on the whole, more complex than the original paradigm that yielded the significant correlation for the constant. The result may be that although interesting sources of individual-differences variance are extracted from what was previously constant across item types, new sources of individual-differences variance may be introduced into what will probably be a more complex constant, so that solving the old problem simply introduces a new one.

To summarize the results of this experiment, nonentrenchment again appears to be a key concept in the understanding of intelligence. The concept again applies both to tasks and to conditions within tasks. The ability to perform the present nonentrenched task was highly correlated with the ability to solve pencil-and-paper reasoning items. In general, metacomponents of nonentrenched tasks seem to be a likely source of important individual-differences variance in measurable intelligence.

Conclusions

Recent laboratory investigations of the information-processing bases of intelligence have been successful in many respects, but correlations of task scores with scores on psychometric measures of intelligence have been less than fully satisfactory. The relatively low level of the correlations could,

of course, betoken a problem in the psychometric tests rather than in the laboratory tasks. Indeed, the psychometric tests are far from perfect. But since we have evidence from numerous sources of a moderate to strong relation between performance on psychometric tests and performance in school, and of a low to moderate relation between performance on the tests and performance in the nonacademic world, it seems that our present best guess is that our laboratory investigations are in need of at least some redirection. I have suggested one new direction for laboratory investigation, the study of relatively nonentrenched tasks, and of relatively nonentrenched stimulus subsets within these tasks. The results of two kinds of experiments studying such tasks--one experiment focusing upon performance components and the other focusing upon metacomponents--provide at least initial evidence for the promise of such a new direction. Performance on these tasks correlates with psychometric test performance at the same .40 to .80 level that psychometric tests correlate with each other.

The results also have possible implications for the measurement of learning and learning potential. Laboratory investigations of learning and learning potential typically study people's abilities to learn new concepts. The present results suggest the importance of studying as well people's abilities to learn new kinds of concepts. Studies of this latter kind might build a closer bridge between the study of learning and that of intelligence than has been built in the past (see Estes, in press).

Finally, I would like to speculate on a possible implication of these results for our educational system in general. There was a time when a classical education, including the study of novel languages such as Greek and Latin, and novel ways of thinking, such as the philosophies of the ancients, was touted as advantageous because it taught an individual how to think, if not what t think. Today, one finds in our secondary schools only the vestiges of a classical

education. Most schools do not even teach Latin or Greek. I wonder whether those who have advocated a classical education have not been saying, in their own way, that the best way to develop intelligent thinking is to study the concepts that I, at least, believe provide the best way to measure intelligent thinking, namely, concepts that are nonentrenched.

On the present view, what moderate correlations have been obtained between laboratory tasks and psychometric tests are probably due at least in part to the moderate levels of nonentrenchment of the tasks and tests that have been used in laboratory intelligence research. If the more complex tasks used by cognitive-components researchers have yielded only slightly higher correlations with mental test scores than have the less complex tasks used by cognitive-correlates researchers, it may be because the more complex tasks are more entrenched, despite their greater complexity. Most people have encountered the tasks studied by cognitive-components researchers--analogies, classifications, series completions, and the like--on numerous aptitude tests, and hence have some familiarity with these tasks. Few people have encountered the tasks studied by cognitive-correlates researchers--name matching of letters in identical and nonidentical cases, scanning of strings of unrelated letters or digits stored in memory for a target letter or digit, taking one's finger off a button and quickly moving it to another button by a lighted target, and the like. Although the processes used in these tasks may be common enough, the tasks certainly aren't. The nonentrenchment of these tasks may account for at least some of their correlation with measured IQ.[5] And even the correlations of complex tasks such as mental rotation tasks with psychometric test performance can be increased by using nonentrenched stimuli such as abstract geometric forms rather than entrenched stimuli such as standard alphnumeric symbols (Pellegrino, Note 6). To the extent that intelligence reflects an individual's ability to adapt to novel (or nonentrenched situations, the study of nonentrenched tasks from task domains drawing upon skills used in the real world seems to provide a useful way to study intelligence.

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[1]Other possible partial sources of the correlation are discussed in Sternberg (1977).

[2]The experiments described here were originally conducted for the purpose of studying what it is that makes some concepts (natural ones) more projectible than others (unnatural ones). (See Sternberg, Note 4.)

[3]Presumably, the novel or nonentrenched letter-series problems on the letter-series tests are the ones that are responsible for most of the individual-differences variation, and hence, for the correlations with the projection task.

[4]The research described in this section was carried out in collaboration with Bill Salter.

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No.	Name	Published Reference
1	Intelligence Research at the Interface between Differential and Cognitive Psychology. January, 1978.	Sternberg, R. J. Intelligence research at the interface between differential and cognitive psychology. Intelligence 1978, 2, 195-222.
2	Isolating the Components of Intelligence. January, 1978.	Sternberg, R. J. Isolating the component of intelligence. Intelligence, 1978, 2, 117-128.
3	Deductive Reasoning. January, 1978.	Sternberg, R. J., Guyote, M. J., & Turner, M. E. Deductive reasoning. In R. E. Snow, P.-A. Federico, & W. Montague (Eds.), Aptitude, learning and instruction: Cognitive process analysis (Vol. 1). Hillsdale, N.J.: Erlbaum, 1980.
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